

Yearly Progress Report

Project Title: Potlining Additives

Covering Period: August 1, 2001 to July 31, 2002

Date of Report: October 23, 2002

Recipient: EMEC Consultants, 4221 Roundtop Road, Export, PA 15632

Award Number: DE-FC07-98ID13664

Subcontractors: Century Aluminum of West Virginia
Century Aluminum of Kentucky
Northwest Aluminum Company/ Golden Northwest Aluminum
SGL Carbon Group

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Project Objective: To examine and test a possibility to improve energy and production efficiency of primary aluminum production cells by promoting wetting of the cathode surface by the aluminum. Wetting is to be achieved by an interaction of titanium in the metal pool and boron oxide impregnated into cathode blocks.

Background: Results with small samples in laboratory and industrial tests were promising. It was found that the impregnation of cathode blocks with boron oxide could be accomplished at elevated temperatures and pressure. A pressure vessel accommodating half-length industrial cathode blocks was acquired.

Status

Phase I involving testing of laboratory samples was concluded in the previous reporting period. Samples immersed in the metal pool of industrial cells showed the desired wetting effect and SEM analysis revealed the formation of TiB_2 particles in the metal immediately adjacent to the carbon-metal interface.

Procedures to impregnate cathode material were established. A suitable pressure vessel operating at high temperatures was procured, installed and operated. Industrial half-length cathode blocks were impregnated with boron-oxide containing melt.

A 6-month Phase II test with seams containing boron oxide was conducted in an industrial cell at the Century Aluminum of Kentucky smelter. Another 6-month test was performed at the Century Aluminum of West Virginia smelter, employing 6 half-length blocks.

Cathode Block Impregnation

Based on laboratory experiments, the conditions were selected to impregnate carbon cathode blocks with boron-oxide containing melt. Accordingly, a custom-made impregnation vessel operating at the desired temperatures and pressures was supplied by Autoclave Engineers in Erie, Pennsylvania. It was delivered and installed with substantial delay and productive operation was started on August 18, 2001, but was interrupted repeatedly by necessary warranty work on the equipment. At the end of the reporting period, six half-length blocks had been impregnated for a six-month test and nine blocks for a 12-month Phase III test. Water leakage caused by the negligence of a building contractor contaminated several completed blocks and their reprocessing is required. The reprocessing will be accomplished as soon as operation of the pressure vessel resumes.

A regime of two 9-hour impregnation periods with an overnight period in between was preceded by an initial heating-up of the block in succession above and immersed in the melt. This yielded typical impregnation values of 12% to 14% weight gain for amorphous blocks and 13% to 16% weight gain for graphitized blocks. Removal of a cathode block from the impregnation vessel is shown in **Figure 1**.



Figure 1 Removal of impregnation block from pressure vessel.

The blocks are subsequently cleaned by using a needle scaler or “gun”. The weight gain is determined after cleaning and compared with the initial weight of the block.

Accidental Exposure to Water

On April 28, 2002 several blocks were exposed to water from several leaks in the roof of the rented building. The roof was in the process of being repaired in a negligent manner.

Damage and remedial action were reviewed in a meeting of EMEC Consultants personnel with consultants. Six blocks prepared for the Phase III test at Century Aluminum of West Virginia were exposed to water. As water reacts with boron oxide, B_2O_3 , to form boric acid, H_3BO_3 , simple drying of the blocks is insufficient; handbook data indicates that water is driven off only at temperatures of 300 °C and higher. An exposure to 400 °C for a duration of 8 hours is considered advisable to remove water that could cause problems in a cell start-up.

Phase II Test at Century Aluminum of West Virginia

Six half-length impregnated amorphous blocks were installed in a pot (for position in the pot see **Figure 2**). The pot was started up in the normal fashion on December 5, 2001. Bath was added first, a day later molten metal. Titanium was added to the metal pool afterwards and kept at a level of 0.05 wt% for the duration of the test.

The pot was operated for six months. Shutdown and partial autopsy was initiated on June 8, 2002. Samples were core-drilled at the locations indicated in **Figure 2**. They were analyzed for boron and sodium content. Generally about half of the initial boron oxide content (as determined from weight gain upon impregnations) remained, whereby no significant differences were observed between upper and lower parts of the sample. The boron content appears to be sufficient to maintain a titanium diboride presence at the block-metal interface. It is suspected that a substantial boron oxide loss occurred in the start-up due to exposure to bath. The sodium content (intercalated sodium and bath components) was somewhat higher in impregnated blocks.

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Partial Pot Autopsy at Century Aluminum of West Virginia

13 June 2002

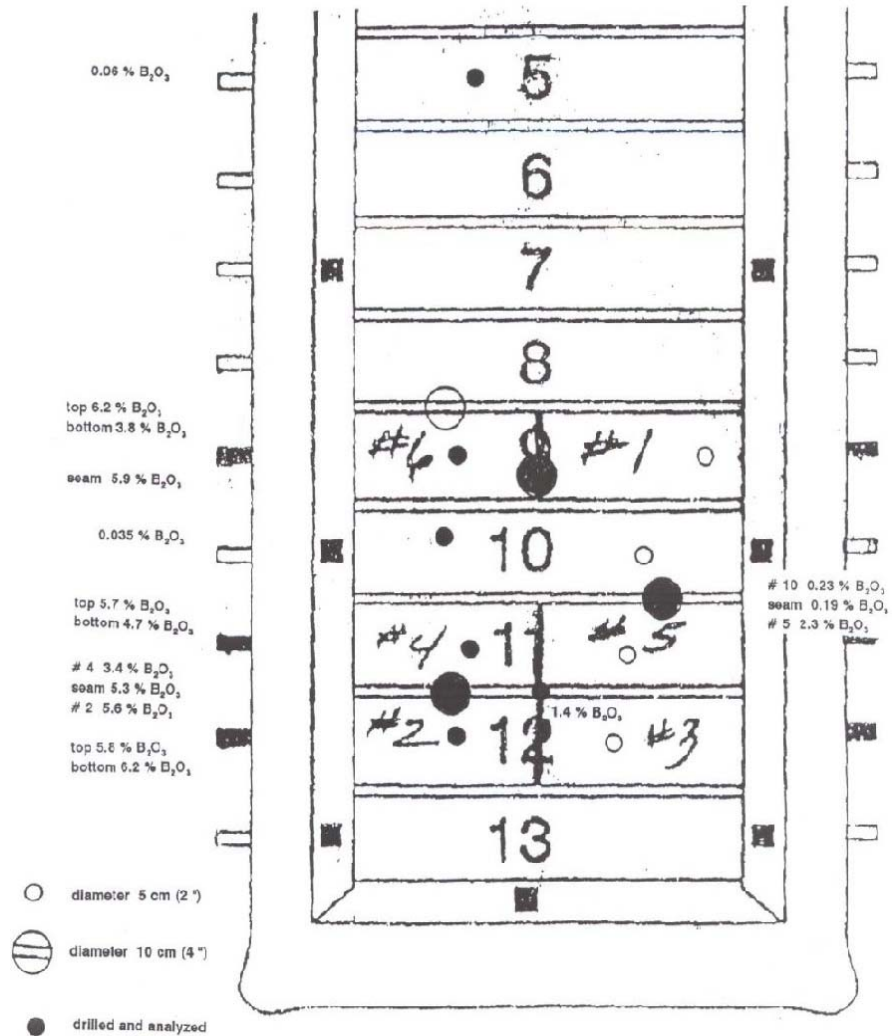


Figure 2. Phase II Test at Century Aluminum of West Virginia – position of impregnated blocks in pot and location of core-drilled samples.

Already the appearance of the blocks showed a decisive difference between impregnated and non-impregnated blocks. There was a black growth that was noticeable on the surface of the impregnated blocks, while no growth was observed on the non-impregnated blocks. The core-samples and the block themselves that had been impregnated were also darker in color than the non-impregnated blocks. Also, blocks containing boron oxide were harder to core-drill than the non-impregnated blocks.

Attempts to attain indication for the wetting of the carbon by metal were not successful. Steel pipes were lowered down to the carbon before tapping of the metal. Some metal was trapped, but after solidification no adherence to carbon was evident. Accumulation of titanium due to the formation of titanium diboride could not be observed by scanning electron microscopy, and this may be expected since any relatively small amount of titanium diboride could enter the bulk of the solidifying metal and then cannot be detected.

Conclusions and Recommendations

The established impregnation procedure yields consistently satisfactory results. With the present staffing and equipment, 3 blocks every two weeks is what can be completed, although, with the addition of some Saturday work in an accelerated mode, 2 blocks per week can be impregnated. For commercial implementation, the production rate could be increased by working around the clock and 7 days a week. A commercial installation would operate several impregnation units simultaneously without increasing manpower proportionally. Blocks could be preheated in a separate furnace, which would increase the productivity of the pressure vessel(s). It is likely that the period between impregnation intervals can be shortened without a qualitative impact. Cleaning of the blocks after impregnation would be mechanized.

Results of the Phase II test in Ravenswood were encouraging insofar as sufficient boron oxide was evidently available at the block surface after a six-month period. Reliable measurements of currents going to individual blocks were not possible and projections in regard to pot performance could not be made. Test with the entire cell equipped with impregnated blocks are highly desirable to provide indications of improved pot performance.

Plans for Next Year:

The original project plans included two six-month Phase II tests and two 12-month Phase III tests. Due to financial and time constraints, some reduction in scope appears to be necessary and will be discussed in the Project Team Meeting on August, 20, 2002.

Patents:

The origin of a key patent, U.S. 5,961,811 (1999-10-05), "Potlining to Enhance Cell Performance in Aluminum Production", precedes the present contractual period. Applications have been filed in Australia, Canada, and Norway.

A patent application, "Carbonaceous Cathode With Enhanced Wettability for Aluminum Production" U.S. Serial no. 09/834,190, filed April 13, 2001, is based on work on the present contract.

Milestone Status Table:

In view of the new reporting requirements and the content of Amendment Number M007, the following formal list of milestones is being presented.

Task II

- 2.1. Complete Task II test at Century of West Virginia.
- 2.2. Complete evaluation of analytical results.
- 2.3. Complete preparation and shipment of blocks for the Goldendale test.
- 2.4. Start of Goldendale Task II test.
- 2.5. Complete Goldendale Task II test.
- 2.6. Complete evaluation of analytical results.

Task III

- 3.1. Restart operation of pressure vessel.
- 3.2. Complete remediation of contaminated blocks.
- 3.3. Complete impregnation of blocks for Century Aluminum of West Virginia.
- 3.4. Start of test at Century Aluminum of West Virginia.
- 3.5. Complete Task III test at Century Aluminum of West Virginia.
- 3.6. Complete evaluation of analytical results.

Reports

- 4.1. Fourth Interim Report submitted.
- 4.2. Fifth Interim Report submitted.
- 4.3. Final Report submitted.

ID Number	Description	Planned Completion	Actual Completion	Comments
1.1	Task I		10/31/01	
2.1	Task II Test at WV	6/23/02	6/23/02	
2.2	Evaluation of WV Test	7/31/02	7/31/02	
2.3	Blocks to Goldendale	8/15/02		
2.4	Start Goldendale Test	9/15/02		* May be eliminated.
2.5	Goldendale Test End	3/15/03		* May be eliminated.
2.6	Evaluation of Goldendale	5/15/03		* May be eliminated.
3.1	Restart Vessel	8/1/02		
3.2	Remediation of Blocks	8/15/02		
3.3	Blocks Complete for WV	10/15/02		
3.4	Start Test at WV	11/15/02		
3.5	Complete WV Test	11/15/03		
3.6	Evaluation of WV Test	1/15/04		
4.1	Fourth Interim Report	10/30/02		
4.2	Fifth Interim Report	10/30/03		Not required.
4.3	Final Report	4/31/04		

* A second Task III test may be substituted.

Budget Data

			Approved Spending Plan			Actual Spent to Date		
Phase/ Task Budget Period			DOE Amount	Cost Share	Total	DOE Amount	Cost Share	Total
	From	To						
Task I	8/1/1998	10/31/2000	357,504	153,216	510,720	358,191	153,511	511,702.09
Task II	3/1/2000	Open	854,819	366,351	1,221,170	768,806	329,489	1,098,294.59
Task III	1/1/2002	Open	581,561	249,240	830,801	56,435	24,186	80,621.86
Year 1	8/1/1998	7/31/1999				145,253	62,251	207,504
Year 2	8/1/1999	7/31/2000				221,891	95,097	316,988
Year 3	8/1/2000	7/31/2001				498,477	213,633	712,110
Year 4	8/1/2001	7/31/2002				317,811	136,205	454,016
Year 5								
Year 6								
Totals			1,793,884	768,807	2,562,691	1,183,432	507,186	1,690,618

Spending Plan for the Next Year:

Month	Estimated Spending				
Entity	EMEC Consultants	Century Aluminum	NWA/ Columbia Falls	SGL Carbon	Total
August	22000	2000	2000	2000	28,000
September	22,000	1000		2000	25,000
October	22,000	1000	2000		25,000
November	22,000	40,000	40,000	1000	103,000
December	22,000	12,000			34,000
January	23,000	10,000	2000	1000	36,000
February	23,000	10,000			33,000
March	28,000	14,000	40,000	2000	84,000
April	23,000	10,000	8000		41,000
May	12,000	10,000	8000	1000	31,000
June	12,000	10,000	8000		30,000
July	12,000	10,000	8000	1000	31,000
Total for Next Year	243,000	130,000	118,000	10,000	501,000